AN OPTICAL PHENOMENON.

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In 1871 in a letter to Tyndall, Joseph LeConte gave an interesting discussion of an ocular illusion which had been previously described. Tyndall communicated it to the *Philosophical Magazine* (XLI., p. 266). The phenomenon was observed in the manner here described:

Pierce a card with a pin. Hold it before the eye at a distance of four to six inches, looking through the hole at a bright background. Place the pin in front of the eye with the head central in the pupil and in close proximity. The pin head will be "seen in the hole," and in an inverted position.

As was pointed out by LeConte, this is not an optical image but a shadow. As proof of this he cites the fact that if a series of holes are made in the card, a similar appearance of the pin head is seen in each hole. He adopted the idea that objects are seen erect, because the nerve fibers at the lowest point on the image see the top of the object in the direction along which those rays have come. He also argued that the inverted appearance of this shadow, which was erect on the retina, was in harmony with this explanation.

The well-known fact that this point in the image is the vertex of a cone of rays, whose base is the pupil of the eye, and that this diverging bundle of rays, when traced outward, does not define the position of any external point, is sufficient explanation of the fact that this line of reasoning has not been generally adopted. Evidently the fact that there are no rays has also been taken into consideration. It does not seem quite evident that nerve fibers at the lower point of the image on which ether waves collapse and deliver their impulses could "see" that these waves had their origin at a definite point, at the top of an object, at a definite distance from the refracting media, in which the radii of curvature of these waves were reversed in direction. And these waves from this point on the object are involved in a summation of waves from other and adjoining points.

Many observers have doubtless had experiences like those which the writer had years ago while doing survey work. Two transit instruments were available, one of which showed the object viewed in erect, and the other in inverted position. A few days of use of either instrument enables the observer to give proper signals to the rod-man in a perfectly automatic way. After having thus become alternately educated, an attempt to use these instruments at random for brief intervals, relying wholly on what he sees through the instrument for the information which is to guide him in making his signals, leads to the most helpless confusion. The observer even seeks to find his way out of his difficulties by comparing what he sees through the instrument with the impression received by a direct view.

Such experience as this appears to justify the conclusion that we see external objects as we have learned how to see them, by help of our other senses. Even then it is a matter of never-ending wonder that we have in our possession certain nerve-fibers that can be trained to see.

There are many interesting features of the phenomenon which LeConte discussed which appear to have escaped his attention. His claim that the sharp outline of the pin head seen in the hole could not be an optical image, since such an image would be so much out of focus as to be invisible, is justified to this extent. The object is in fact also visible in its real position in shadowy outline. It appears transparent, and the inverted shadow of the pin head is mentally projected outward and appears to be visible through the object itself. Every detail of the letters on a printed page is visible through this enlarged and transparent appearance which the object itself presents, due to an out-of-focus image on the retina.

The sharpness of outline of the shadow decreases as the hole is made greater in area. This is due to penumbral effects. A black card gives more sharply defined results than a white one. A tube having the pierced card at one end and the pin head at the other may be applied to the eye, in such a way as to cut off all side light. The head may be covered with a black cloth, which is also wrapped around the tube. The shadows are then as sharply defined as an optical image could be. If the black sateen cloth be thrown over the head, and the eyes be directed towards a bright sky, a multitude of cir-

cular images like pin hole images will be seen between the crossed fibers. Some of these are due to the right eye and some to the left. A pin head in front of either eye will show multitudes of inverted pin head shadows.

A circular disk of white paper having a diameter of 1 mm. or slightly less, mounted upon a black card will also have upon it a sharply defined black shadow of the pin head, if the side facing the observer is illuminated. The paper disk must be near enough to the eye so that its image on the retina is out of focus, as in other cases where the pin hole is used. At various points on the glowing end of a cigar, when observation is made in a darkened room, similar shadows may be observed. A small blot of ink on a sheet of white paper will yield a white shadow of the pin head. The same result is given by a hole in a white card, if the card is illuminated and observation is made through the hole at a dark background.

If the reflected image of the full moon or of a bright star from the convex surface of a lens be used instead of the pin hole in a card, the inverted shadow will be observed. If the reflecting surface is concave, the shadow will appear erect if the eye is placed between the reflector and its principal focus. If the eye and pin are in the divergent beam beyond the principal focus, the shadow of the pin head will appear inverted.

It is evident that when the shadow on the retina is erect, it appears inverted, and *vice versa.*

The eye lens and retina may be replaced by a convex lens and a paper screen upon which an image of the moon may be cast. A pin closely in front of the lens will show no shadow. If another convex lens be now placed in front of the lens representing the eye, the moon's image will be out of focus. The moon's image may be in front of or behind the screen, according to the position of the second lens. The shadow of the pin will then appear.

The capacity for accommodation of this artificial eye is unlimited, and the second lens may be dispensed with. The screen being placed between the lens and the image, the shadow of the pin will appear erect on the screen. When placed beyond the image, it will appear inverted.

If an opera glass be focused on a street lamp 50 meters away a

pin head between the eye and the eye-lens will produce no shadow on the retina. If the glass be focused for a nearer object, an erect shadow will appear. If focused for a more distant object, the shadow will appear inverted. A hole through a card and with a bright background may be viewed by means of the opera glass. The hole may have any diameter from 0.05 to 1.5 cm. The distance of the card must be adapted to the diameter of the hole, and may vary from close contact with the object lens to three or four meters, the glass being focused for a more distant object. The results are as indicated above. The setting sun surrounded by bright clouds may be used as an object, if viewed through the foliage of trees thirty or forty meters distant, the glass being focused for an object more distant than the trees. The mass of foliage will be dotted with pin head shadows. Each opening through the leaves acts in a manner similar to the pin hole.

In all of the cases described, the shadow upon the retina is by some mental act projected outward in space. An interesting question arises concerning its apparent position. LeConte says that in his experiments it appears in the hole in the card. Perhaps it would be proper to say that it is seen through the hole. The hole itself may have a diameter of about one third that of the pin head, and the pin head then appears smaller than the hole. Its apparent size depends somewhat on the diameter of the hole.

If a pin is placed back of the card and in erect position so that it is visible through the hole, it may be so placed that it has the same apparent size as the shadow. If the pin is at a distance of 30 cm. from the eye, and the card is at a distance of 15 cm., the shadow and the pin will have the same apparent size. The appearance of the inverted shadow and the erect pin is as shown in Fig. 1.

Fig. 1.

This suggests an interesting device whereby the line of sight of the two eyes and the capacity for muscular adjustment may be exam-

ined. Pierce a card with two pin holes, at such a distance from each other that when placed at half the distance of distinct vision from the eyes, they may be seen as one. This can be done by drawing lines across the ruled lines of a page of white paper, and crossing the ruled lines symmetrically so that at the top of the page the lines are farther apart and at the bottom they are nearer together than the two eyes. Pierce pin holes at each intersection of the ruled lines with the cross lines. If held in front of the eyes so that the cross lines are seen double, the two inner images of the lines will appear to cross. At this distance apart thus determined two holes will appear as one. Place a card having holes thus placed in front of the eyes. Mount two pins in front of the pupils so that the two shadows appear superposed in the superposed images of the holes. Two pins may now be placed back of the card so that when viewed through the holes they will also appear superposed. The two holes and the four pins will then present the appearance shown in Fig. 1. This arrangement locates two points along the line of sight of each eye. The holes may be in separate cards which close the ends of two tubes, through which the observations are made. These tubes, together with the pins, should be capable of screw adjustments.

When the pin hole is viewed through a tube which is lined with dark paper, the card serving to close the outer end of the tube, it may be used for an examination of certain imperfections in the eye. For example, in my own case one eye shows a minute hole with a bright background to be of uniform appearance. Viewed by the other eye a rather sharply defined shadow is shown in the center of the hole. This is due to a slight irregularity in the curvature of the outer surface of the cornea. This is due to a grain of gunpowder which was blown into the eye from a horse-pistol which was discharged from a distance of about 35 cm., into the lower part of the face, about fifty years ago. The grain of powder was visible for many years, but has been gradually absorbed. A slight distortion of closely ruled parallel lines indicates that an irregularity of the surface still persists. The shadow seen in the pin hole shows that light is not uniformly spread over the retina when a slightly divergent beam of light enters the pupil. Any opacity in the crystalline lens would also produce a shadow upon the retina.